

# **The Effects of Weather on Ice Conditions in the Amundsen Gulf, N.W.T.**

M.O. Hammill

Arctic Biological Station  
Department of Fisheries and Oceans  
555 St. Pierre Boulevard  
Ste. Anne de Bellevue, Quebec H9X 3R4

May 1987

**Canadian Manuscript Report of  
Fisheries and Aquatic Sciences  
No. 1900**



Government of Canada  
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M.O. Hammill

Arctic Biological Station  
Department of Fisheries and Oceans  
555 St. Pierre Blvd.  
Ste-Anne-de-Bellevue, Québec H9X 3R4

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Cat. No. Fs 97-4/1900

ISSN 0706-6473

Correct citation for this publication:

Hamill, M.O. 1986. The effects of weather on ice conditions in  
the Amundsen Gulf, N.W.T. Can. MS Rep. Fish. Aquat. Sci.1900:  
iv + 10 p.

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## ABSTRACT

Hammill, M.O. 1986. The effects of weather on ice conditions in the Amundsen Gulf, N.W.T. Can. MS Rep. Fish. Aquat. Sci.1900: iv + 10 p.

Timing of ice formation and breakup in the Amundsen Gulf were examined for the years 1964-1974. Wind and temperature appear to be equally important in determining the date of ice retreat. A strong negative correlation was found between time of ice retreat and ice advance.

Key words: Amundsen Gulf, ice, weather

## RÉSUMÉ

Hammill, M.O. 1986. The effects of weather on ice conditions in the Amundsen Gulf, N.W.T. Can. MS Rep. Fish. Aquat. Sci.1900: iv + 10 p.

Les saisons de formation et de dispersion de la glace dans le golfe d'Amundsen ont été examinées de 1964 à 1974. Le vent et la température sont également important pour déterminer la date du retrait de la glace. Une forte corrélation négative a été observée entre la saison de la retraite de la glace et celle de la formation de la glace.

Mots-clés: Le golfe d'Amundsen, glace, météorologie

## INTRODUCTION

The timing of breakup and freezing of sea ice in the Canadian Arctic varies considerably from year to year. This variability affects man's activities in the north and, although the links are not clear, has significant biological implications. All Arctic communities depend on the delivery of supplies by sealift. For marine life the beginning of the phytoplankton bloom in the spring is controlled by light which in turn is affected by ice and snow cover (Grainger 1975). Considerable information is available on ice conditions in the Amundsen Gulf region of the Canadian Arctic. The aim of this paper is to look at these data and relate them to wind, temperature and regional pressure patterns.

## MATERIALS AND METHODS

Ice Summary and Analysis reports for the Canadian Arctic published by the Department of Transport were examined for the years 1964 to 1972. Data on ice conditions for 1973 and 1974 were obtained from the Sea Ice Atlas (Lindsay, 1977). Weekly weather conditions were summarized in the Ice Summary and Analysis reports. Ice condition charts for these reports were constructed from information obtained on bi-monthly flights over the area from May 21 to July 9 and August 28 to October 22 and weekly flights from July 10 to August 29.

For sealift, vessels must move east from Tuktoyaktuk around Cape Bathurst into the Amundsen Gulf to serve communities such as Holman on Victoria Island (Fig. 1). Therefore the Amundsen Gulf was considered to be ice free when 80% of the gulf was open water and if a channel was open around Cape Bathurst. Freeze up was complete when 80% of the gulf was covered by new ice. Using these definitions ice advance and retreat were divided into early, medium and late ice years.

If ice formation was not complete when the ice observations were discontinued on October 22, these years were classified as late ice years.

## RESULTS

### a) Ice Conditions in the Amundsen Gulf

The Amundsen Gulf is covered by first year ice with very little, if any, multi-year ice present at all. Normally a polynya is located off the southern tip of Banks Island and extends to Cape Bathurst on the mainland. The location of the polynya varies considerably, being displaced as far east as Holman in some years, as far west as Sachs Harbour or not existing at all (Table 2). There doesn't appear to be any relationship between presence of the polynya, its location and the breakup pattern for the year.

## b) Ice Breakup

During years of early ice retreat open water appears first at the southeast end of the gulf near the entrance to Dolpin and Union Strait or along the mainland coast east of Cape Parry (Table 1). Expansion of this open water occurs in a north and westward direction. Total time for the gulf to become clear of ice is about 4 weeks from the first appearance of open water. In 1971 the polynya was located in the southeast end of the gulf. Break up involved an expansion of the polynya in all directions and was complete 4 weeks after the first noticeable change in polynya size.

In medium ice years break up patterns are less clear cut. Open water generally forms around Cape Parry and expands in an east, north and west direction. The progression of breakup is constantly hampered by drifting ice from the Beaufort Sea and the failure of loose ice in the gulf to drift out. Breakup takes approximately 7 weeks beginning between June 25 and July 9.

In late ice years open water appears first along the coastline and progresses towards the middle. Generally it takes 5 to 7 weeks for the gulf to become clear of ice beginning around July 30. In 1964, 1967, and 1974 the gulf itself was clear of ice, early in the summer but a clear channel around Cape Bathurst failed to appear.

## c) Ice Advance

No particular differences were detected between the patterns of ice advance for the three categories. New ice formation usually began in Prince of Wales Strait and extended south. Soon after, ice also formed in Minto Inlet and Prince Albert Sound. Generally, the southeast portion of the gulf was the last to freeze. In two of the eleven years examined, ice formation also began in the southeast portion of the gulf at the same time as ice formation began in the north. In both instances this occurred during late advance years.

In early ice years ice formation began during the week of September 24 and 80% coverage was completed two weeks later. In medium ice years, ice formation didn't begin until October 8 and was 80% complete by October 22. During late ice years ice formation didn't begin until October 22.

## d) Predominant Winds

Significant differences in the frequency distribution upward direction were found between early and late breakup years ( $\chi^2 = 15.1$  df = 5, p 0.05) and between medium and late breakup years ( $\chi^2 = 14.7$ , df = 5, p 0.05) (Table 3). In years of early ice breakup, winds were predominantly from the east. In medium ice years the winds appeared to be evenly divided between westerlies and easterlies. In late ice years the predominant wind directions were from the west, northwest and north. Differences in predominant wind directions between the three categories of ice advance were not significant.

During early breakup years the frequency of above normal temperature was greater than medium ice years ( $\chi^2 = 17.4$ ,  $df = 1$ ) and late ice years ( $\chi^2 = 18.9$ ,  $df = 1$ ) (Table 4). No differences were found in the frequencies of above normal or below normal temperatures between medium and late breakup years and between early, medium and late ice advance years.

Spearman correlation analysis revealed a strong negative relationship between time of ice advance and ice retreat; for example, early ice breakup followed by late ice advance ( $r_s = -0.92$ ,  $N = 9$ ,  $p = 0.05$ ; Siegel 1956).

#### f) Pressure Synopsis

Normally during the summer months a very weak high pressure system is located over the Arctic Ocean while a weak but extensive low pressure system covers Baffin Bay and the eastern Arctic. The high pressure zone becomes progressively stronger in the fall and winter and becomes associated with an intense high centered over Lake Baikal, Siberia. The result is a ridge of high pressure extending from Siberia to the Mackenzie Valley. At this time of year the predominant winds become northwesterly. Semi-permanent low pressure systems are located over the Aleutian Islands and Iceland. By midwinter a high forms over the Arctic Ocean. As spring approaches, this centre drifts eastward. By April-May the high has become established over the Ellesmere-Greenland region (Markham, 1975). At the same time the trough over the Aleutians extends into central Alaska and combines with the high moving east from Siberia. The result is a gradual shift in wind direction to southeast winds. During the summer months a weakening of the high pressure systems occurs and the low pressure systems are displaced to the north of their winter routes (Rae, 1951).

In early ice retreat years the western Arctic continues to be dominated by a series of high pressure systems located over Prince Patrick Island to Ellesmere Island.

In medium ice years, there is a displacement of the high pressure systems to the south over the Beaufort Sea, Victoria Island region. Low pressure systems are predominantly found over the Arctic Ocean and the Queen Elizabeth Islands. In late ice retreat years the high pressure systems are displaced further to the south, being located over Alaska, and the mainland south of the Amundsen Gulf. The low pressure systems again dominate the high Arctic. Four weeks prior to break up the general pattern changes, high pressure systems again dominate the high Arctic, with low pressure systems over the mainland.

Relationships between pressure patterns and time of freeze up were less distinct than for breakup. In early ice advance years high pressure systems dominate the Prince Patrick region, low pressure systems being found over Baffin Island and the Boothia Peninsula. In medium and late ice years there is considerable variability in the positioning of the pressure systems making a distinct pattern difficult to detect.

## DISCUSSION

Formation and maintenance of the polynya depends primarily on the offshore winds which usually form in the area during April-May (Markham, 1975). Weather information wasn't complete enough to examine the polynya any further. It is probable that eastward displacement of the polynya involves an eastward displacement of the high and low pressure systems from their normal locations at this time of year.

It is clear that the locations of the high and low pressure systems are directly related to the ice retreat pattern. In other studies for the Beaufort Sea (Rogers, 1978) and Davis Strait (Crane, 1978) the authors suggest summer temperature has the greatest influence on ice retreat. In the Amundsen Gulf both temperature and wind direction appear to be important. Years of early ice breakup are characterized by warmer than normal temperatures. The predominant wind direction is from the southeast, helping to clear ice out of the Amundsen Gulf into the Beaufort Sea. Medium ice years have below normal temperatures but southeast winds still predominate. During years when ice breakup is delayed, cool winds blow over the Beaufort Sea pack ice from the west and northwest and cold winds from the north prevail. These winds are associated with below normal temperatures and inhibit the movement of ice from the Amundsen Gulf into the Beaufort Sea during the spring.

A definite negative relationship exists between the timing of breakup and ice freeze up. This contradicts the findings of Crane (1978) for Davis Strait. The relationship may be related to the persistence of the spring pressure patterns. In early ice retreat/late ice freeze up years, spring-like pressure conditions prevail throughout the summer into the fall. There doesn't appear to be any association between time of break up/freeze up in the Davis Strait and the Amundsen Gulf which is not surprising. Davis Strait is much larger and has a north-south orientation. The Amundsen Gulf is much more enclosed and has a more east-west orientation in addition to the considerable distance between the two. Time of break up in the adjacent Beaufort Sea (Markham, 1975) agreed with the findings of this study in seven of eleven years. The Beaufort Sea is much more open than the Amundsen Gulf and is bounded on the north side by the polar ice pack.

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Table 1. Classification of years by time of ice retreat and ice advance.

|                | <u>Early</u>            | <u>Medium</u>    | <u>Late</u>            |
|----------------|-------------------------|------------------|------------------------|
| Ice<br>Retreat | July 23, 1968           | August 27, 1965  | September 10, 1964     |
|                | July 23, 1970           | August 13, 1969  | September 10, 1966     |
|                | July 25, 1971           | August 13, 1972  | September 10, 1967     |
|                | July 23, 1973           |                  | September 10, 1974     |
| Ice<br>Advance | October 8, 1964         | October 22, 1965 | after October 22, 1968 |
|                | October 8, 1967         | October 22, 1966 | after October 22, 1969 |
|                | approx. October 8, 1974 | October 22, 1970 | after October 22, 1971 |
|                |                         | October 22, 1972 | after October 22, 1973 |

Table 2. Location of polynya during the years 1964-1974.

| <u>Year</u> | <u>Location</u>                                                                                                           |
|-------------|---------------------------------------------------------------------------------------------------------------------------|
| 1964        | no polynya                                                                                                                |
| 1965        | polynya extends from Cape Lambton to Cape Parry and eastwards over Darnley Bay                                            |
| 1966        | polynya displaced east of Darnley Bay and extends to Holman                                                               |
| 1967        | polynya failed to form - thin ice where polynya normally located                                                          |
| 1968        | no polynya                                                                                                                |
| 1969        | polynya in normal location                                                                                                |
| 1970        | polynya in normal location                                                                                                |
| 1971        | polynya extended from Holman across Prince Albert Sound - a small channel extended to the Beaufort Sea along the mainland |
| 1972        | very small polynya formed off Sachs Harbour                                                                               |
| 1973        | no polynya                                                                                                                |
| 1974        | very narrow polynya extended from Sachs Harbour to Cape Bathurst                                                          |

Table 3. Summary of wind directions. Only the dominant wind direction for each week was recorded from the Ice Summary and Analyses Reports.

| Category         | Wind Direction | Observed Frequency |
|------------------|----------------|--------------------|
| Early Breakup    | N              | 6                  |
|                  | S              | 6                  |
|                  | E              | 9                  |
|                  | W              | 3                  |
|                  | NW             | 0                  |
|                  | SE             | 5                  |
| Medium Breakup   | N              | 9                  |
|                  | S              | 7                  |
|                  | E              | 13                 |
|                  | W              | 11                 |
|                  | NW             | 5                  |
|                  | SE             | 2                  |
| Late Breakup     | N              | 16                 |
|                  | S              | 9                  |
|                  | E              | 7                  |
|                  | W              | 16                 |
|                  | NW             | 10                 |
|                  | SE             | 3                  |
| Early Freeze up  | N              | 3                  |
|                  | S              | 2                  |
|                  | E              | 5                  |
|                  | W              | 1                  |
|                  | NW             | 1                  |
|                  | SE             | 1                  |
| Medium Freeze up | N              | 10                 |
|                  | S              | 7                  |
|                  | E              | 11                 |
|                  | W              | 5                  |
|                  | NW             | 2                  |
|                  | SE             | 4                  |
| Late Freeze up   | N              | 9                  |
|                  | S              | 7                  |
|                  | E              | 7                  |
|                  | W              | 9                  |
|                  | NW             | 3                  |
|                  | SE             | 3                  |

Table 4. Temperatures for years 1964-1972

| Ice Condition  | Year      | Observed Frequency |              |
|----------------|-----------|--------------------|--------------|
|                |           | Above Normal       | Below Normal |
| Early Breakup  | 1968      | 6                  | 0            |
|                | 1970      | 4                  | 2            |
|                | 1971      | 3                  | 0            |
|                | T O T A L | 13                 | 2            |
| Medium Breakup | 1965      | 3                  | 6            |
|                | 1969      | 0                  | 9            |
|                | 1972      | 2                  | 6            |
|                | T O T A L | 5                  | 21           |
| Late Breakup   | 1964      | 2                  | 9            |
|                | 1966      | 7                  | 5            |
|                | 1967      | 0                  | 11           |
|                | T O T A L | 9                  | 25           |
| Early Advance  | 1964      | 1                  | 1            |
|                | 1967      | 1                  | 2            |
|                | T O T A L | 2                  | 3            |
| Medium Advance | 1965      | 1                  | 3            |
|                | 1966      | 1                  | 2            |
|                | 1970      | 7                  | 2            |
|                | 1972      | 2                  | 4            |
|                | T O T A L | 11                 | 11           |
| Late Advance   | 1968      | 7                  | 2            |
|                | 1969      | 5                  | 1            |
|                | 1971      | 7                  | 4            |
|                | T O T A L | 19                 | 7            |

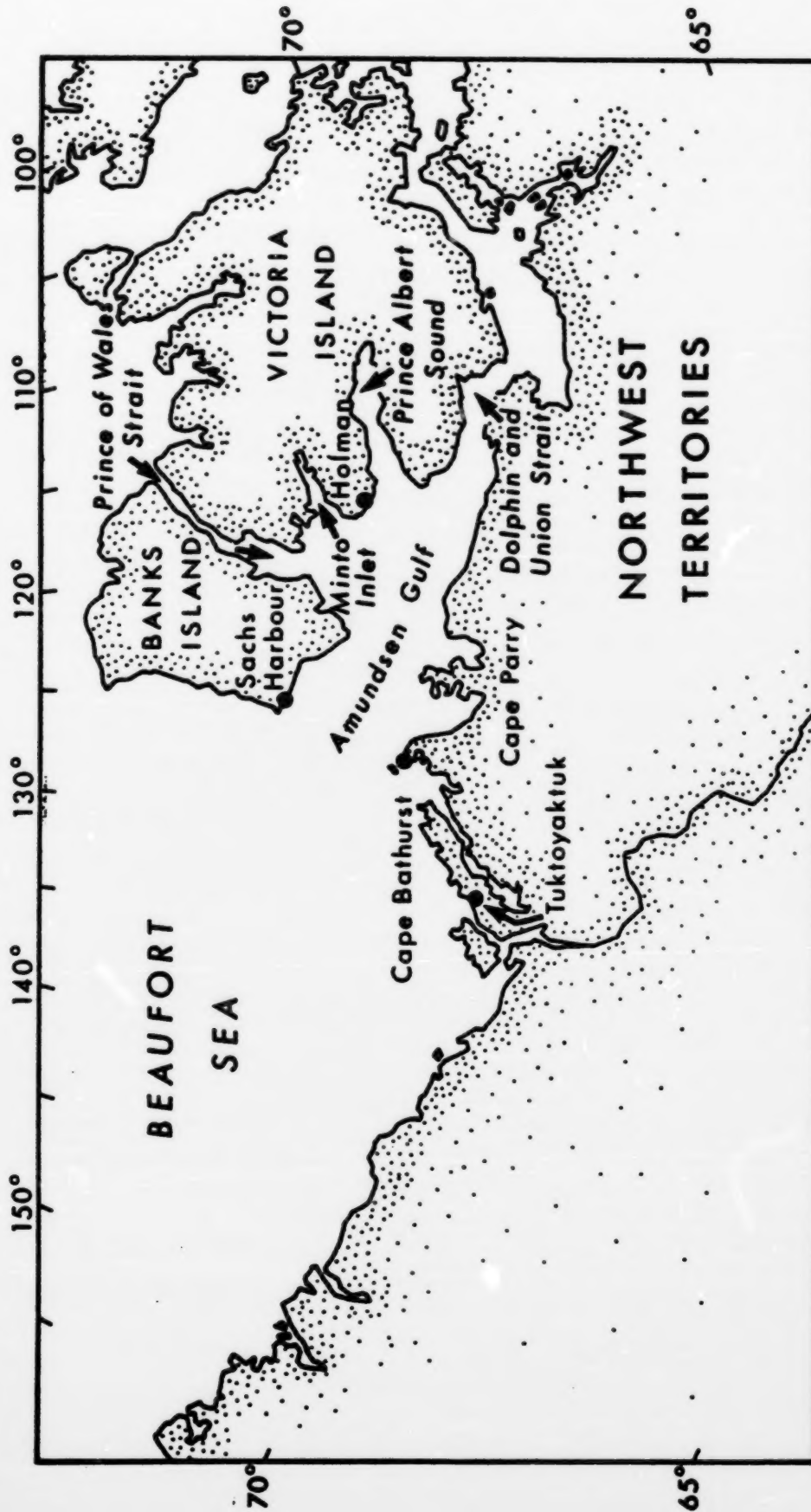


Figure 1. Area examined for pattern of ice advance and ice retreat.